

# **Climate Impacts on Future Ozone Concentrations in California: Explaining the Uncertainty**

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# California is Famous for Ozone

- California currently experiences some of the highest ozone concentrations in the United States
- Ozone concentrations reflect a balance between local emissions and meteorology
- Climate change will alter meteorology
  - How will ozone concentrations respond?

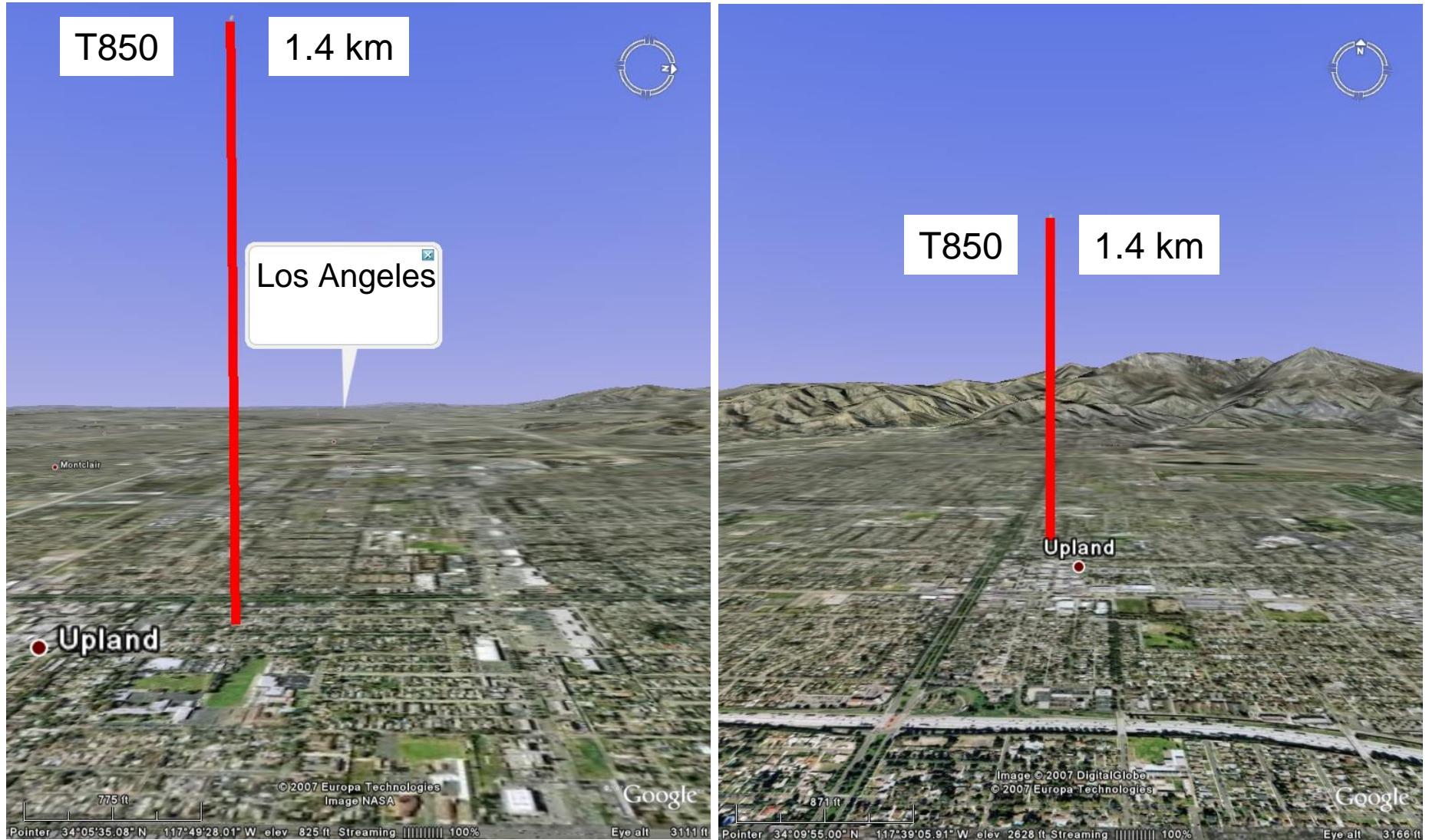
# Approach#1: Dynamic Downscaling

- Two Basic Steps:
  - GCM output drives Regional Climate Model (RCM)
  - RCM output + Emissions Inventory drives Chemical Transport Model (CTM)
- Simulate enough future ozone episodes to characterize statistical properties
- Advantages
  - Includes our full understanding of atmospheric processes
  - Can extrapolate outside of historical conditions
- Disadvantages
  - We might not understand all of the atmospheric processes
  - Limited by missing information
  - Very computationally expensive

# Approach #2: Statistical Downscaling

- Use historical measurements to find relationship between ozone and meteorology
- Directly predict future ozone concentrations based on GCM output
- Advantages
  - Skips the computationally expensive stuff in the middle
  - Based on observed behavior, so guaranteed to be correct for historical conditions
- Disadvantages
  - Black box approach
  - Dangerous to extrapolate outside historical conditions

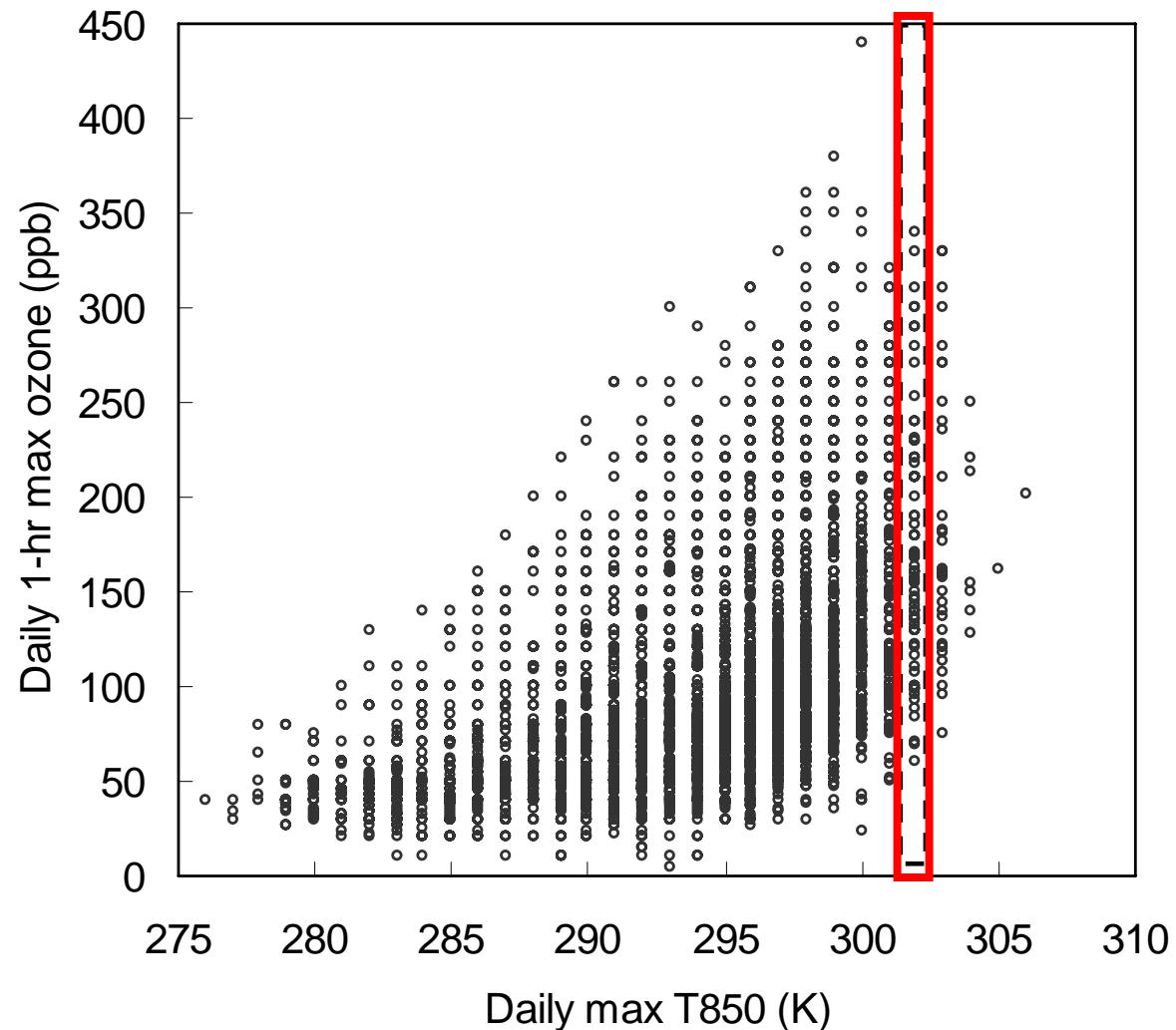
# Statistical Downscaling for Ozone With Upper Air Temperature (T850)



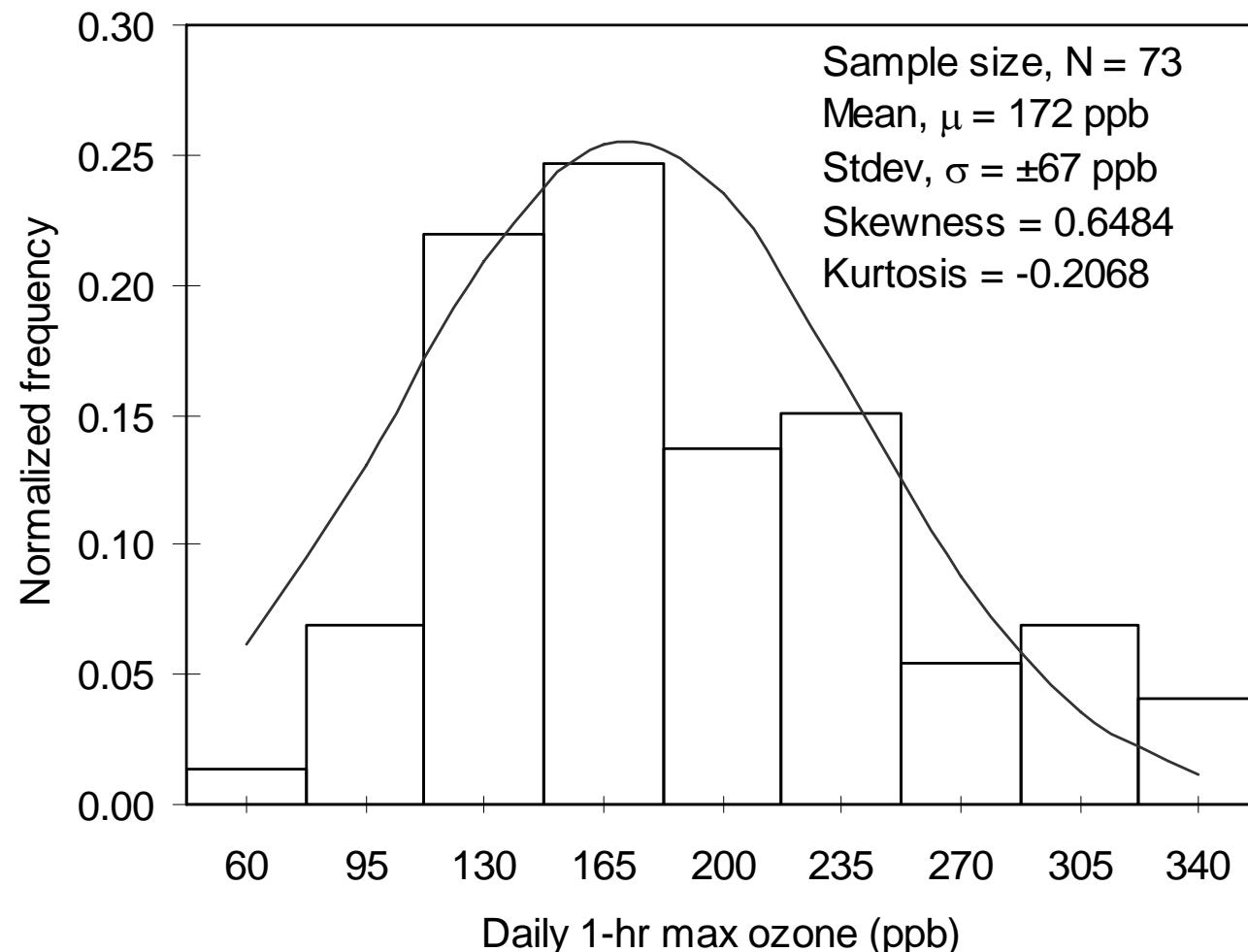
# Why Should T850 be correlated with Surface Ozone?

- Ozone is formed in the atmosphere and mixes to the surface
- Warmer temperatures increase the speed of chemical reaction
- Warmer temperatures increase the rate of emissions for organic compounds
- A layer of warmer air above cooler air is stable
  - Caps the atmosphere trapping pollutants

# Observed Ozone Concentrations vs T850 at Upland (SoCAB), CA (1980-2004)



# Frequency Distribution: Observed daily 1-hr max ozone concentrations for T850=302K Upland (SoCAB), CA (1980 - 2004)

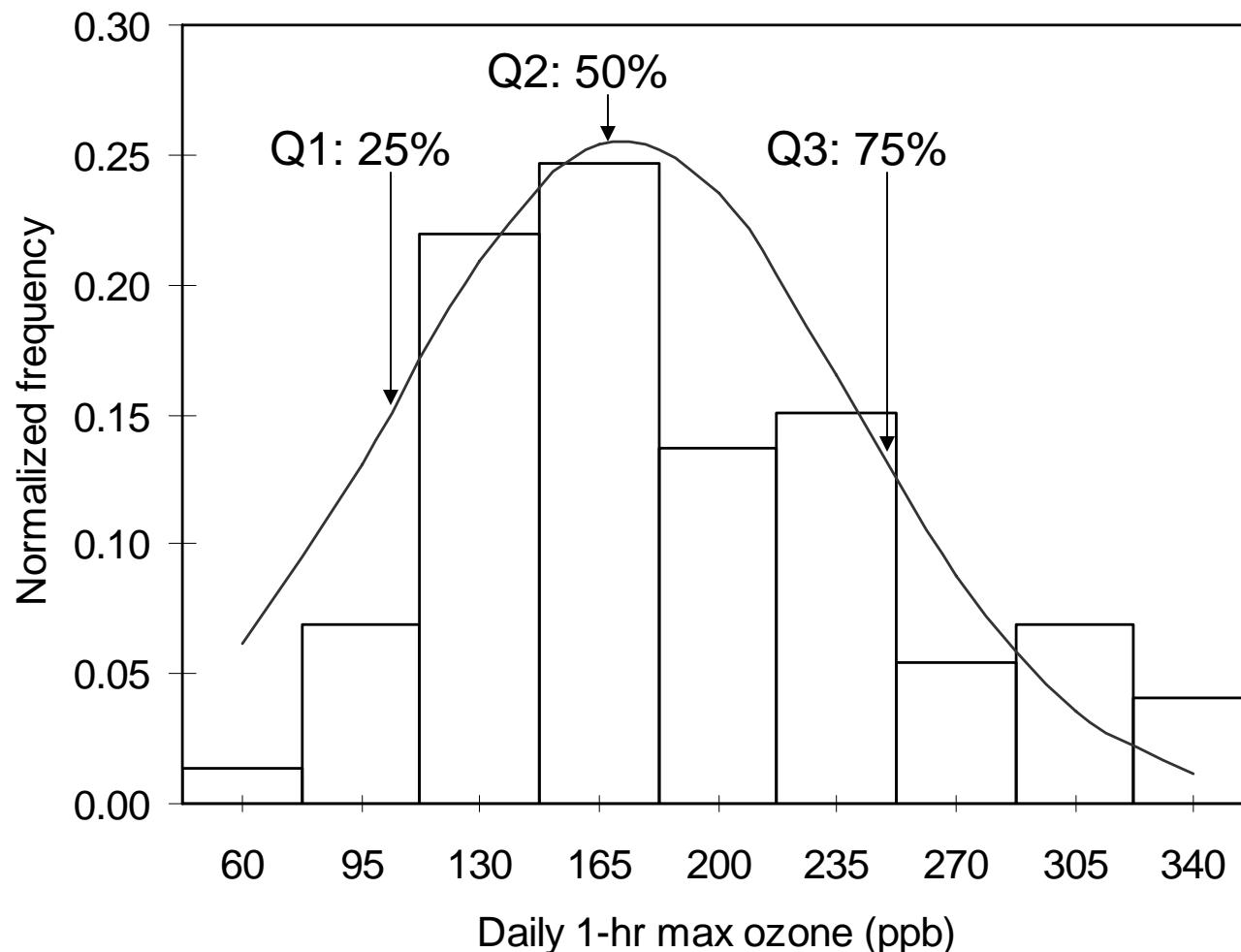


# Ozone Quartile Concentration Ranges

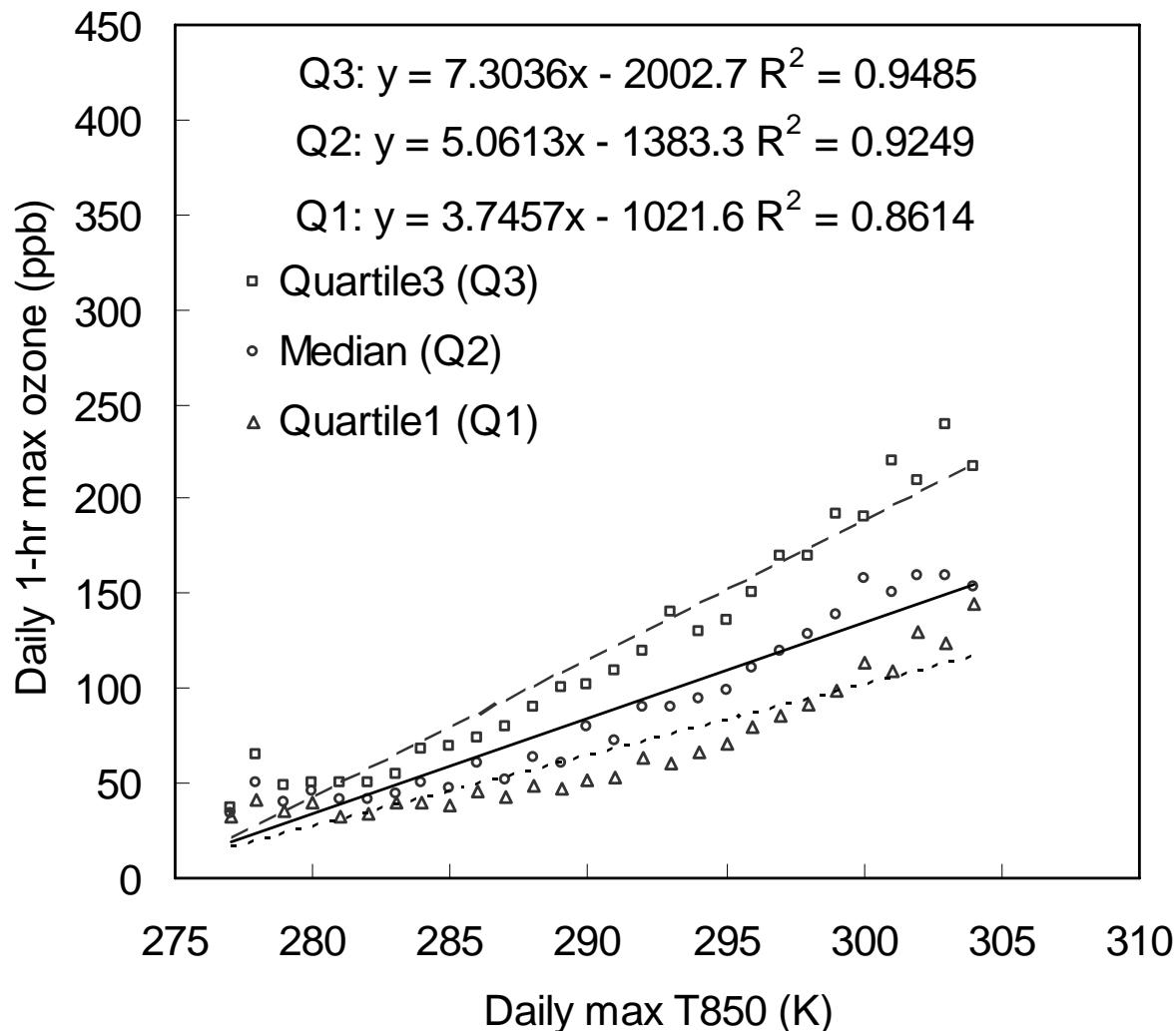
Q1 – 25% of all values below

Q2 – 50% of all values below

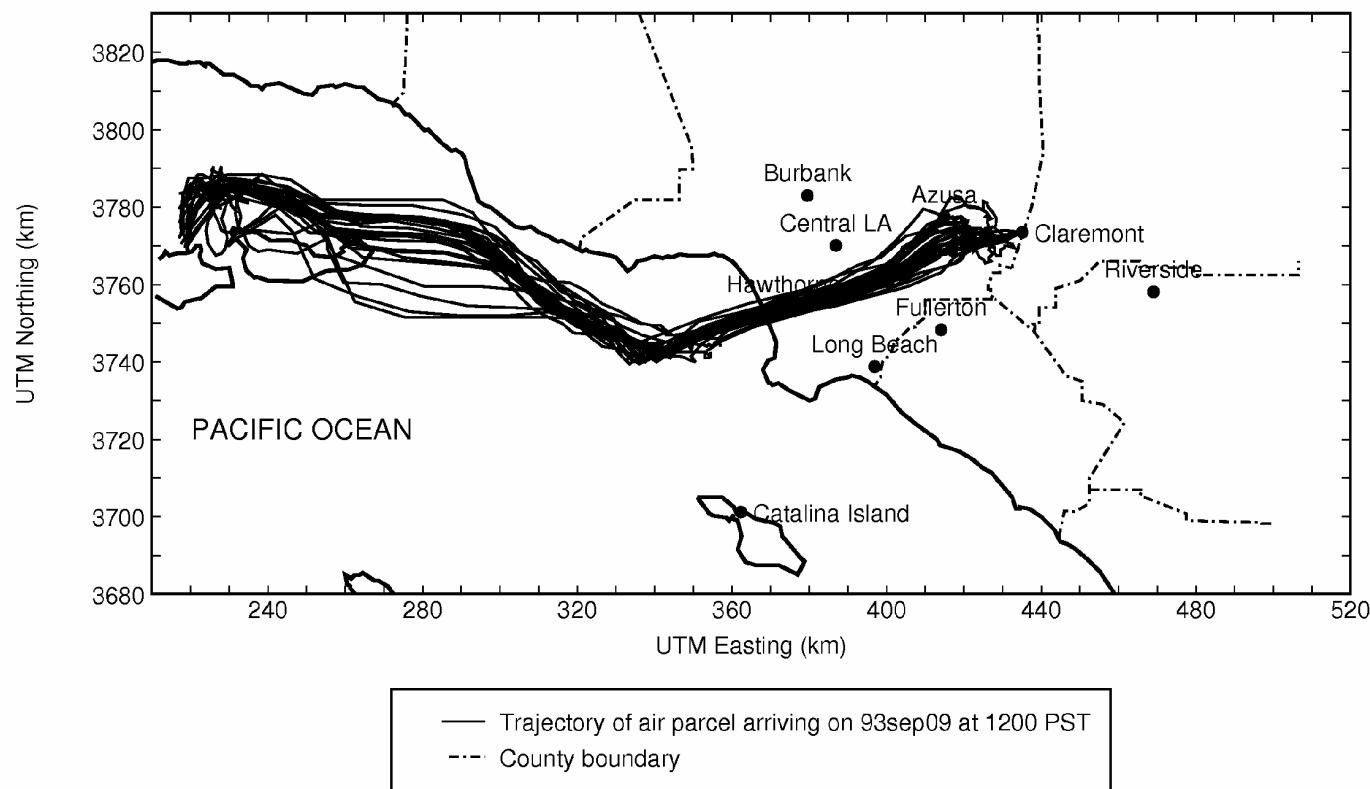
Q3 – 75% of all values below



# Quartile Ozone Concentrations vs.T850 at Upland CA (1980-2004)



# Air Parcel Trajectories Arriving at Claremont During Typical On-Shore Flow

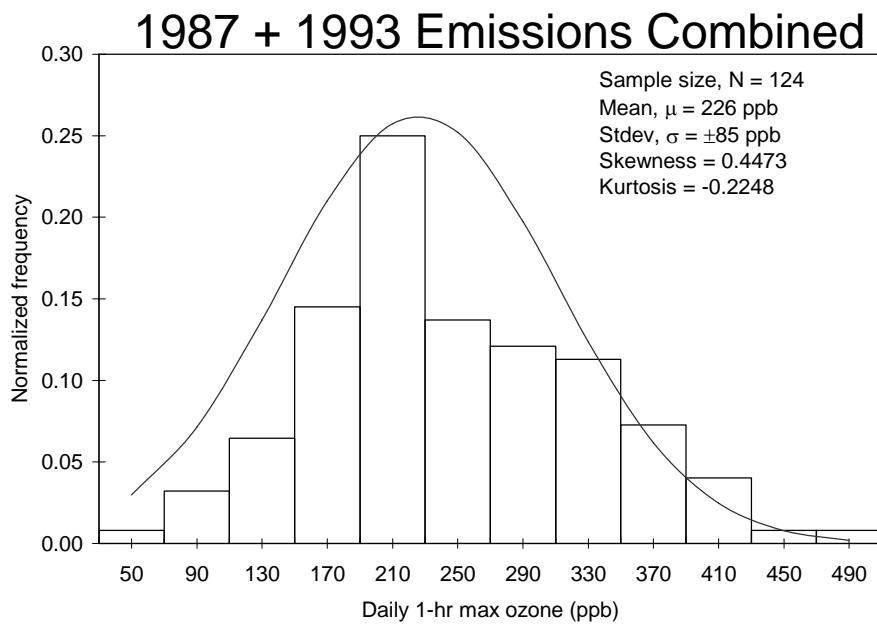
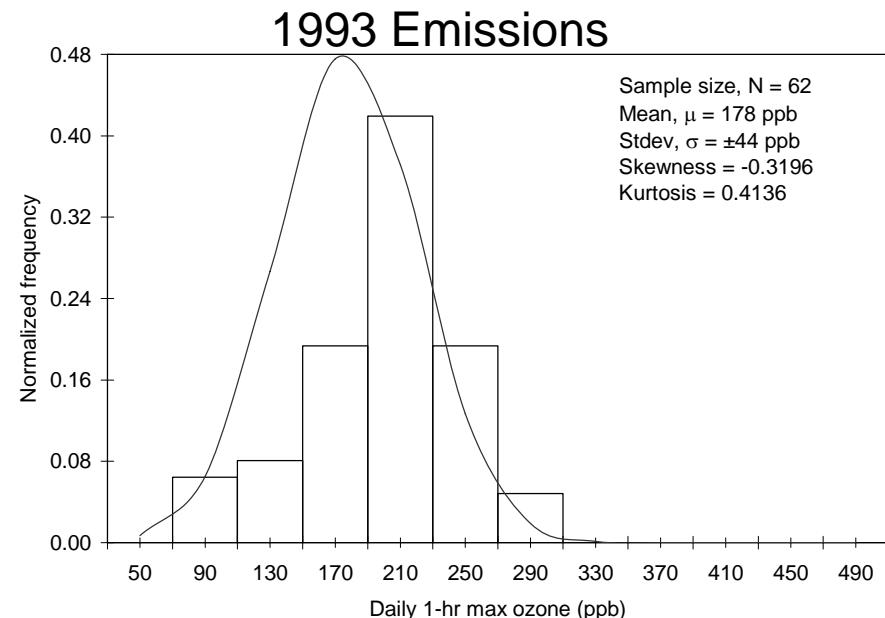
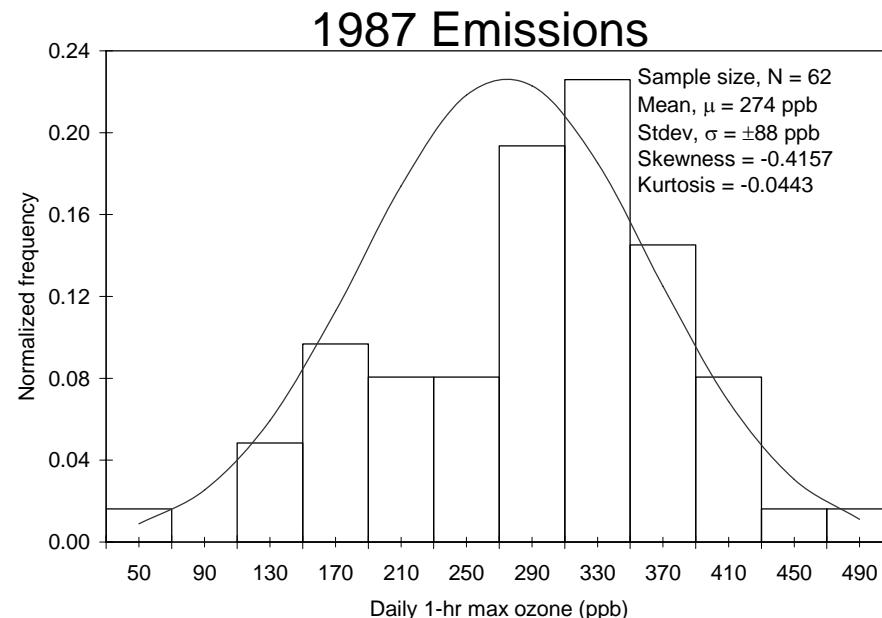


# List of additional variables that were perturbed during the Monte Carlo simulations of ozone formation

Variable	Variation amount
Temperature	$\pm 5$ °C
Mixing height	$\pm 20\%$
Relative humidity	$\pm 10\%$
Overall emissions	$\pm 30\%$
Initial conditions for VOCs	$\pm 30\%$
Initial condition for background ozone	Between 30 ppb and 60 ppb
Biogenic and evaporative emissions	Temperature dependent scaling

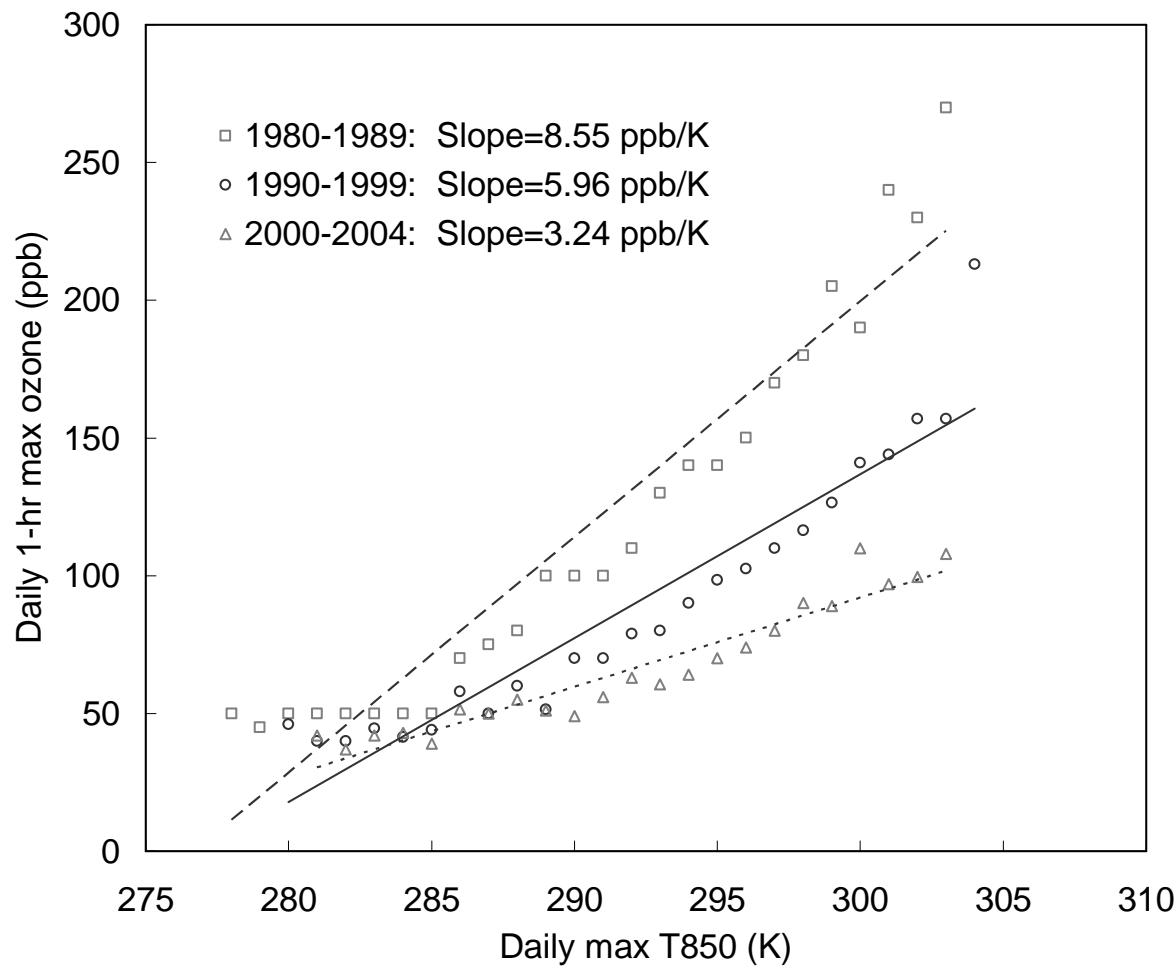
# 1-Hr Max. Ozone Frequency Distribution at Claremont, CA

T850=302K .



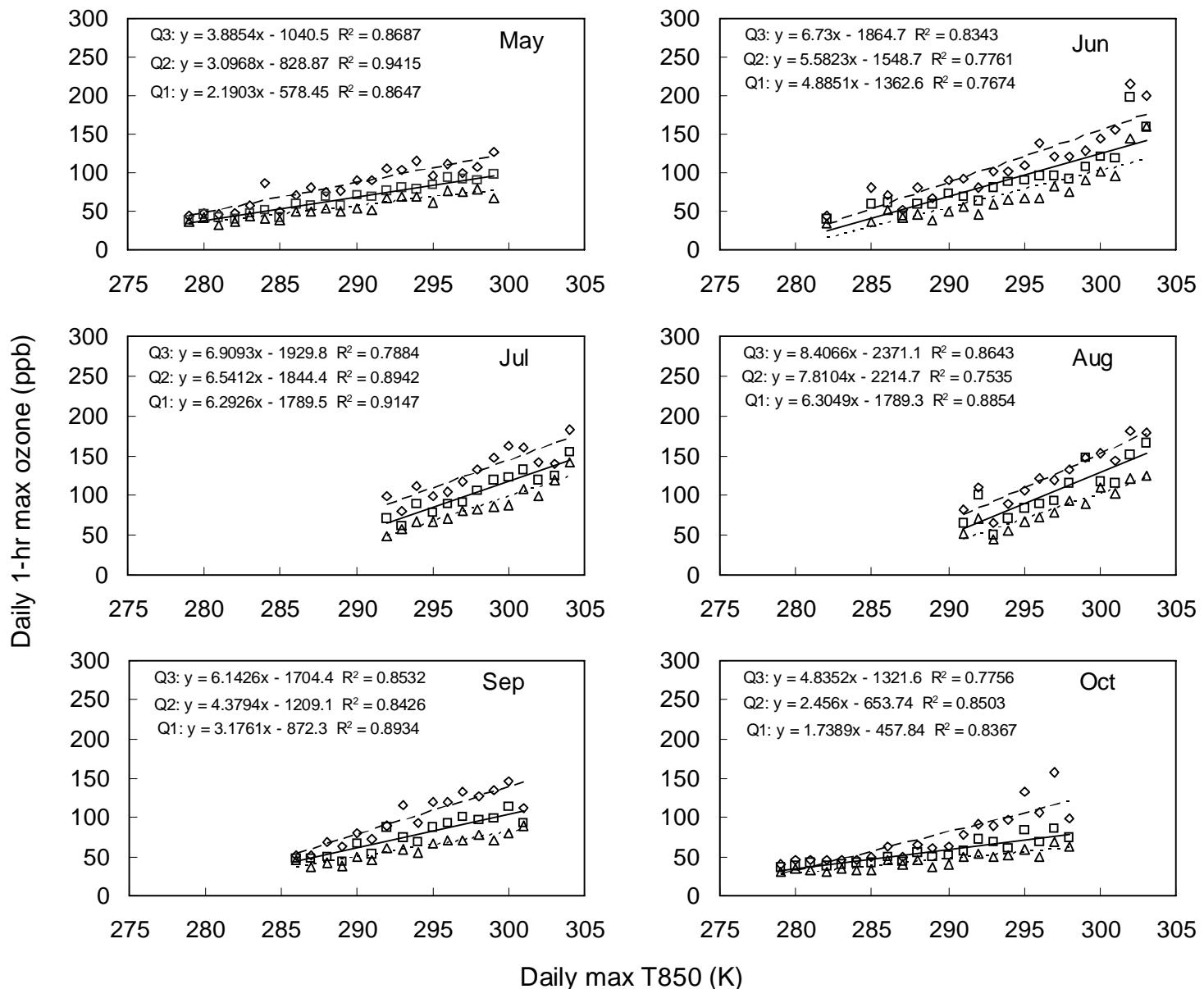
Changes in emissions between 1987 and 1993 had a greater effect on ozone than any other variable.

# Long Term Trends Are Apparent in the Measured T850 vs. Ozone Relationship



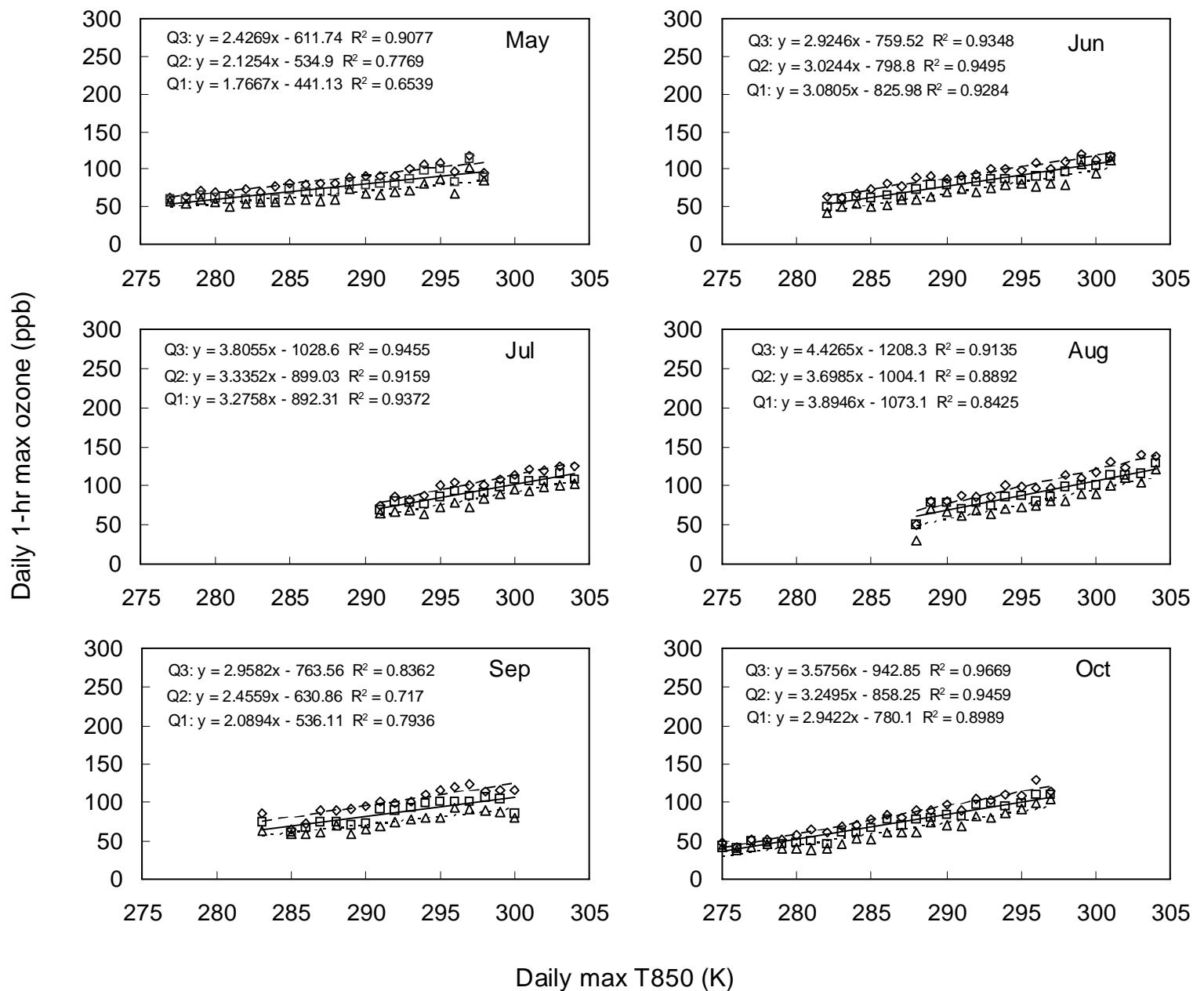
Upland, CA  
(1990 – 2004)

# Seasonal (Monthly) Trends in the Ozone-T850 Relationship

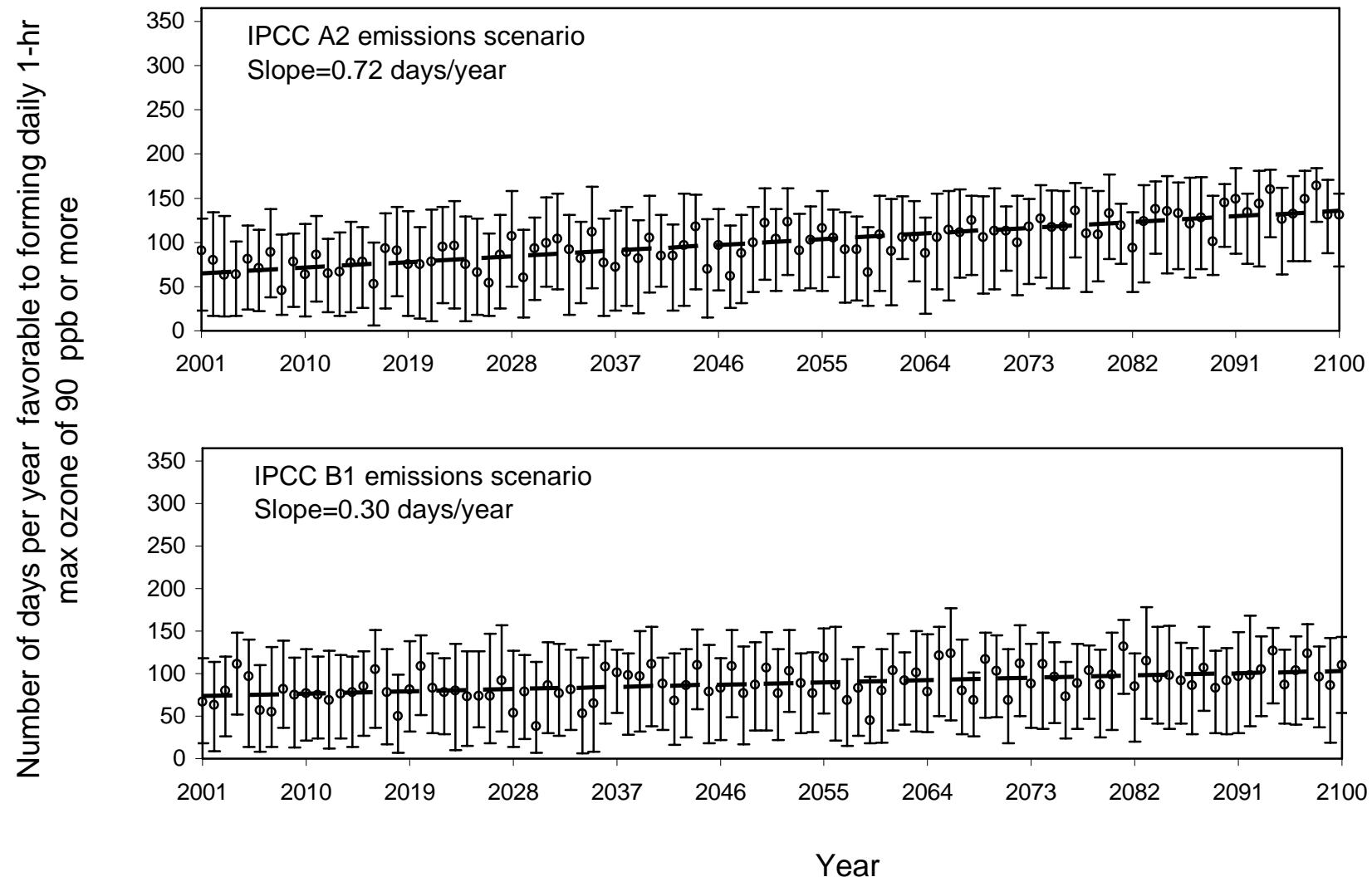


# Seasonal (Monthly) Trends in the Ozone-T850 Relationship

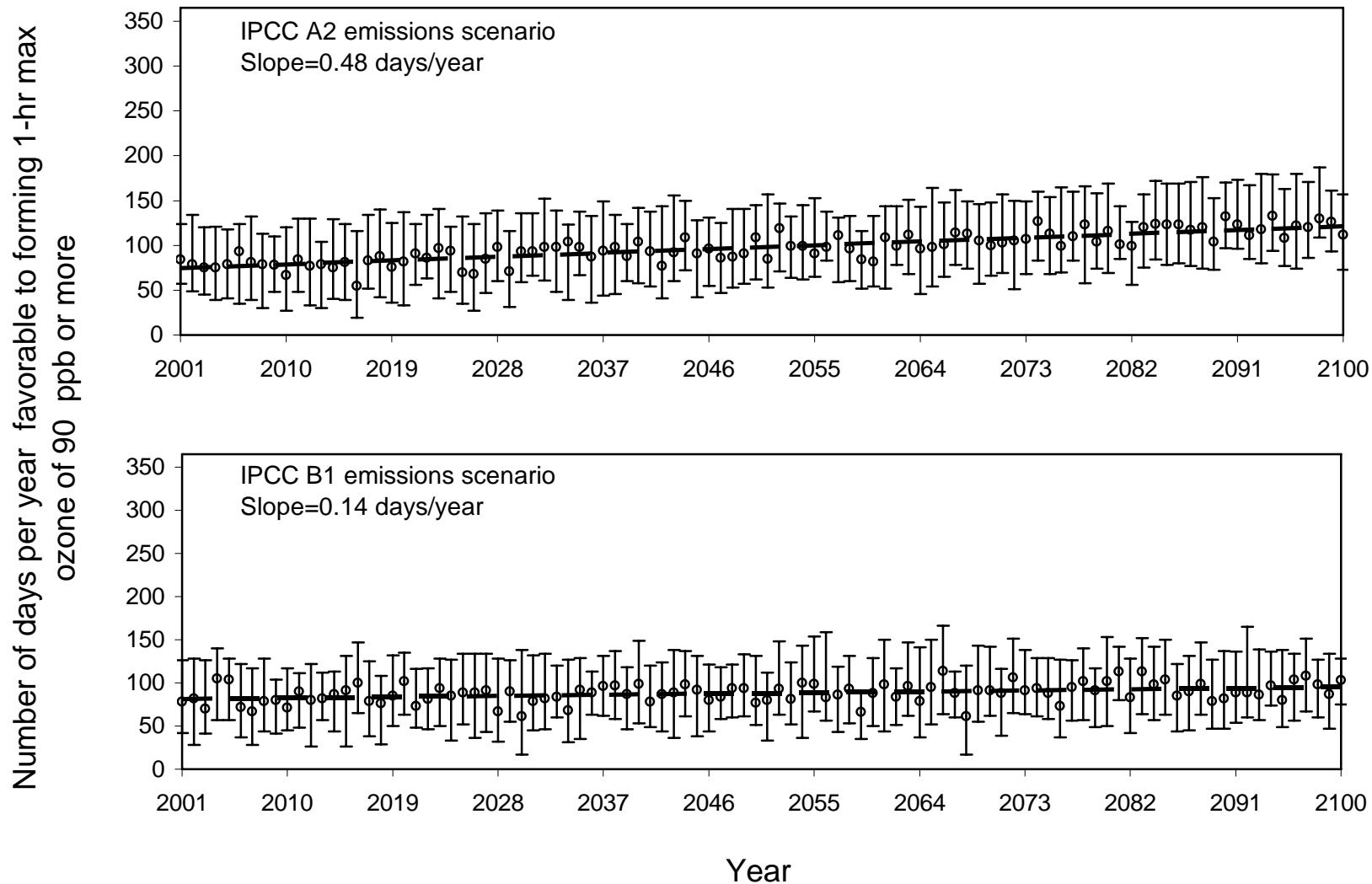
Parlier CA  
(1990 – 2004)



# Number of Days per Year Conducive to Forming 1-hr Max Ozone > 90 ppb in Southern California.



# Number of Days per Year Conducive to Forming 1-hr Max Ozone > 90 ppb in Central California.



# Conclusions

- Statistical downscaling of ozone results provides an efficient method to estimate future ozone concentrations
- Long-term emissions trends account for most of the scatter in the historical ozone-T850 relationship
- Seasonal variation in ozone-T850 relationship is likely caused by biogenic effects
- Future increases in temperature will encourage more ozone formation
  - SoCAB:  $A2=0.7\text{days/yr}$ ;  $B1=0.3\text{ days/yr}$
  - SJV:  $A2=0.5\text{days/yr}$ ;  $B1=0.1\text{days/yr}$
- California will need additional emissions reductions to compensate for this “Climate Penalty”

# Acknowledgements

- California Air Resources Board Project # 04-349
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